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(54) **EVENT MANAGEMENT APPARATUS, SYSTEMS, AND METHODS**

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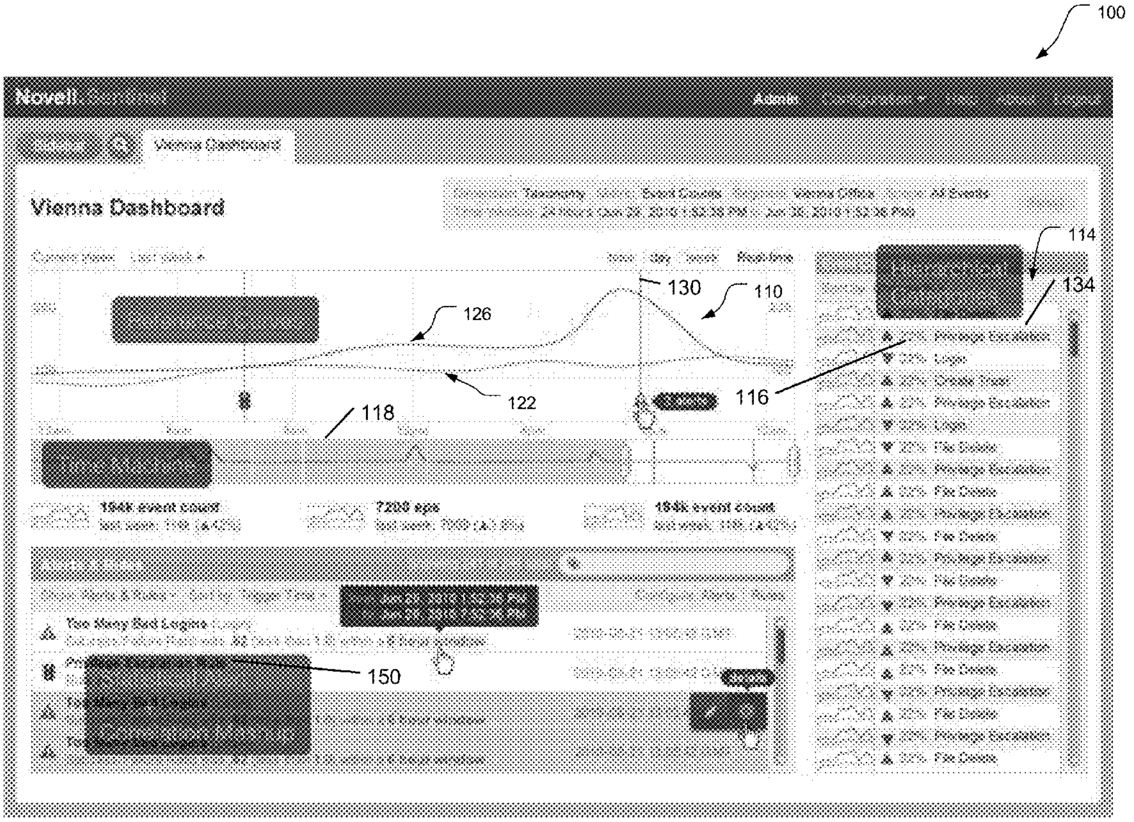
(57) **ABSTRACT**

Apparatus, systems, and methods may operate to generate a reference statistical model of an operating system, such as a computer system, and display the reference statistical model as a hierarchical, segmented time series event stream graph, along with a graph representing current behavior of the system. The event stream graph may be derived from one or more streams of security events. Additional operations may include receiving requests to display further detail respecting discrepancies between the reference statistical model and the current behavior. Other apparatus, systems, and methods are disclosed.



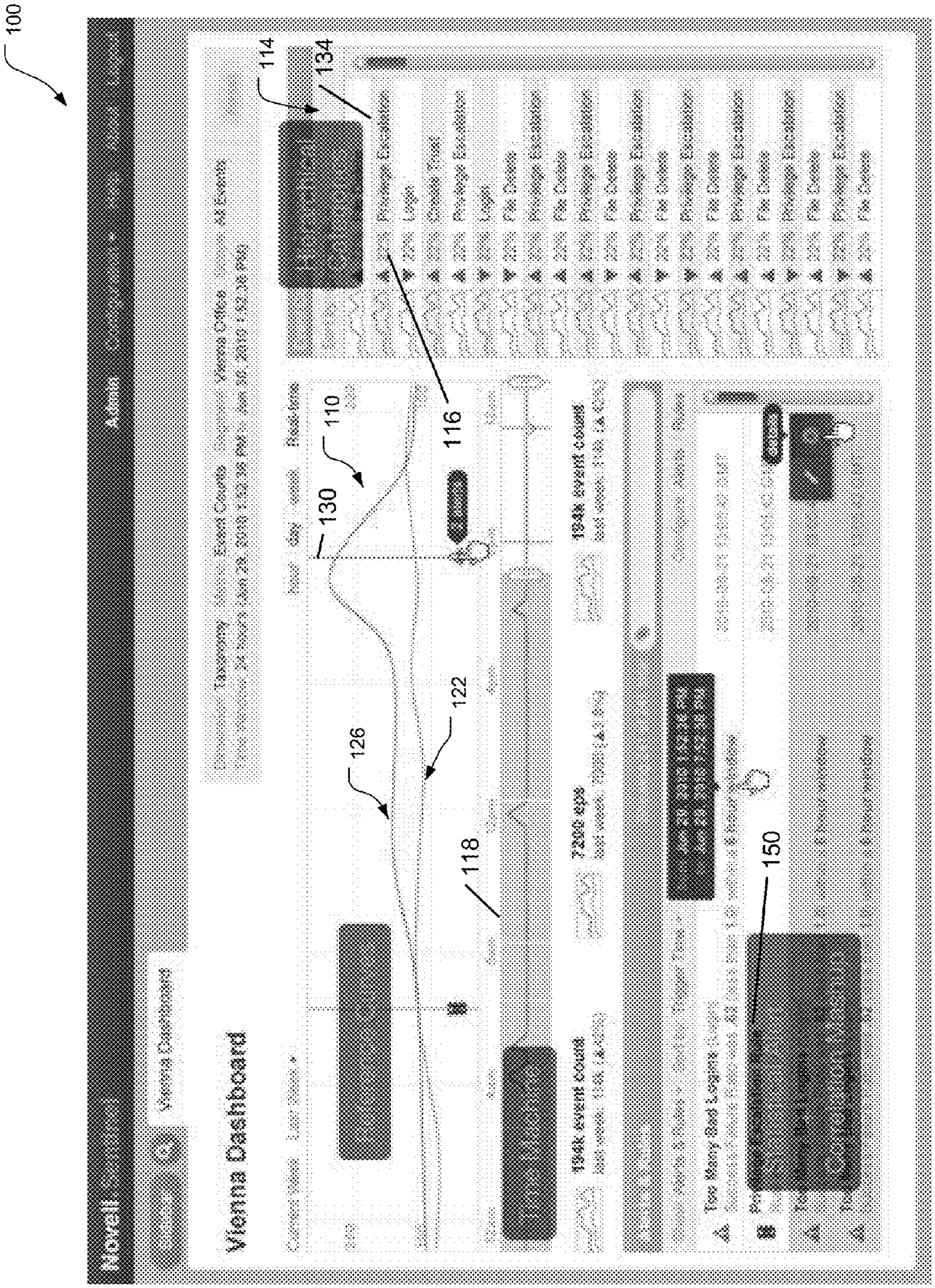

100
Novell
Vienna Dashboard
Vienna Dashboard
Admin
110
114
116
118
122
126
130
134
150
7200 eps
194k event count
Too Many Bad Logins
Privilege Escalation
Logon
File Delete
Real-time

FIG. 1

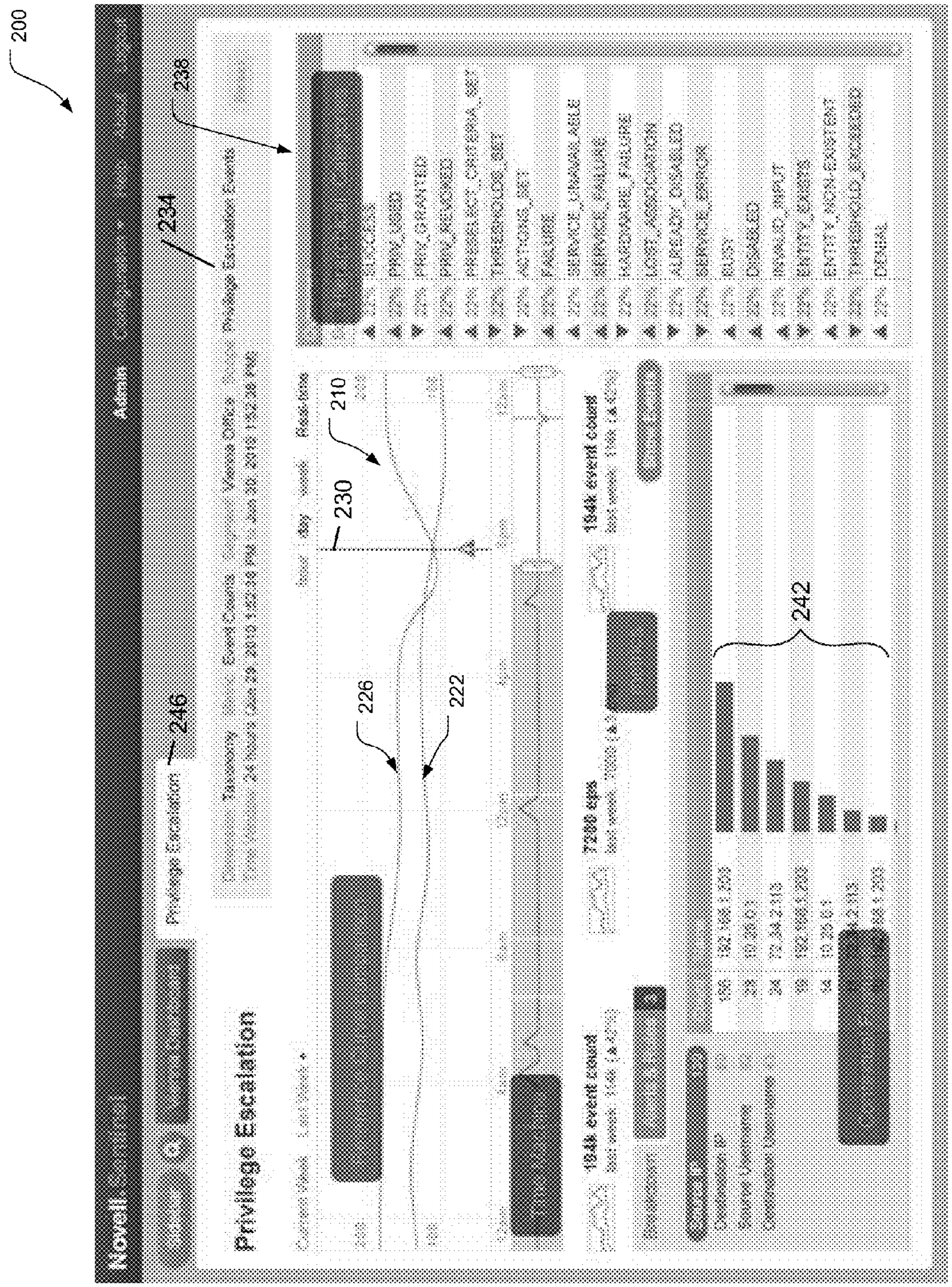

200
Novell
Admin
Privilege Escalation
Privilege Escalation
246
234
238
210
230
226
222
242
Privilege Escalation Events
Real-time
PRIV_USED
PRIV_GRANTED
PRIV_REVOKED
PRESELECT_CRITERIA_SET
THRESHOLDS_SET
ACTIONS_SET
FAILURE
SERVICE_UNAVAILABLE
SERVICE_FAILURE
HARDWARE_FAILURE
LOST_ASSOCIATION
ALREADY_DISABLED
SERVICE_ERROR
BUSY
DISABLED
INVALID_INPUT
ENTITY_EXISTS
ENTITY_NON-EXISTENT
THRESHOLD_EXCEEDED
DENIAL
184k event count
7288 eps
184k event count

FIG. 2

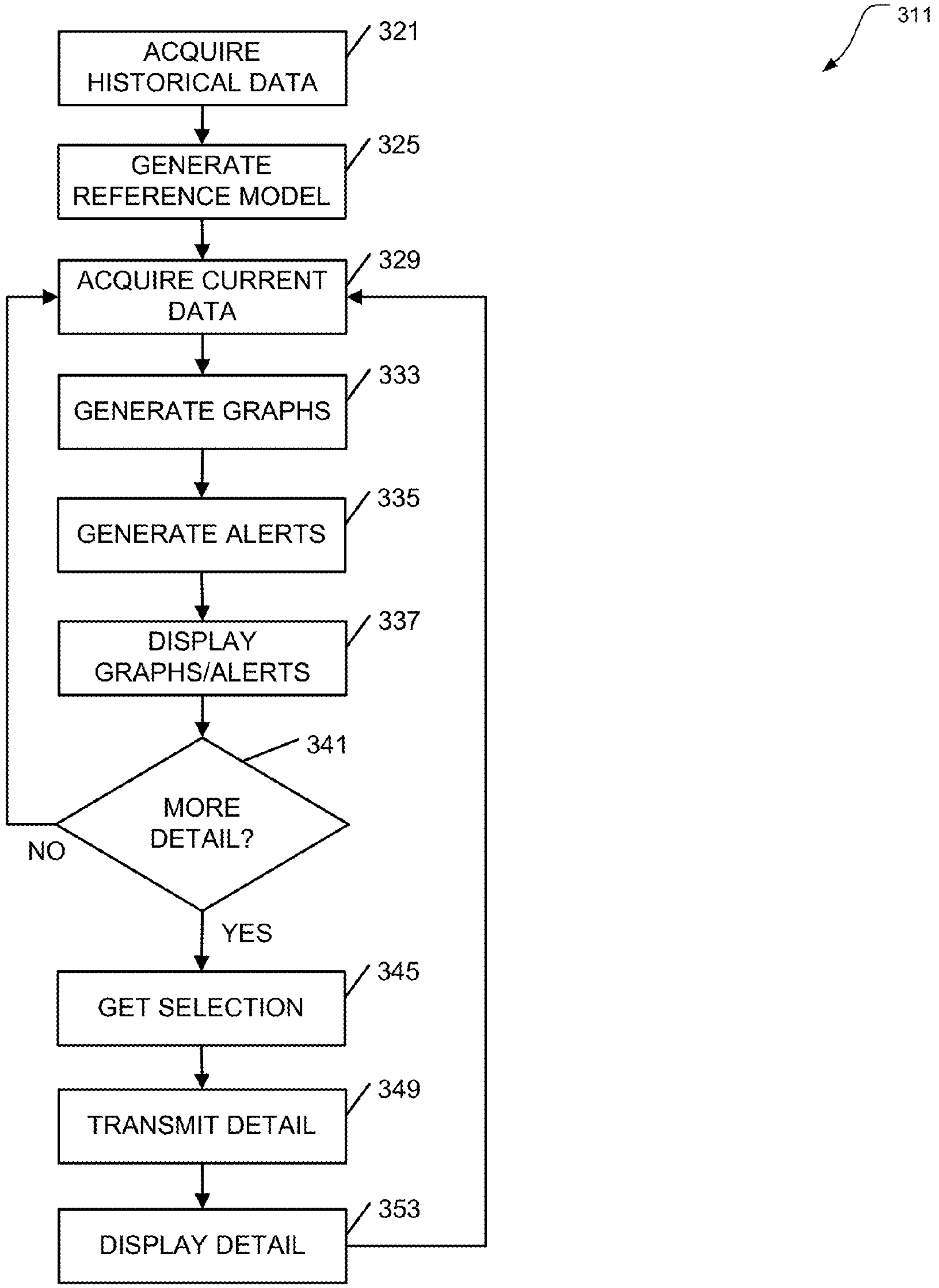

311
ACQUIRE HISTORICAL DATA
321
GENERATE REFERENCE MODEL
325
ACQUIRE CURRENT DATA
329
GENERATE GRAPHS
333
GENERATE ALERTS
335
DISPLAY GRAPHS/ALERTS
337
MORE DETAIL?
341
NO
YES
GET SELECTION
345
TRANSMIT DETAIL
349
DISPLAY DETAIL
353

FIG. 3

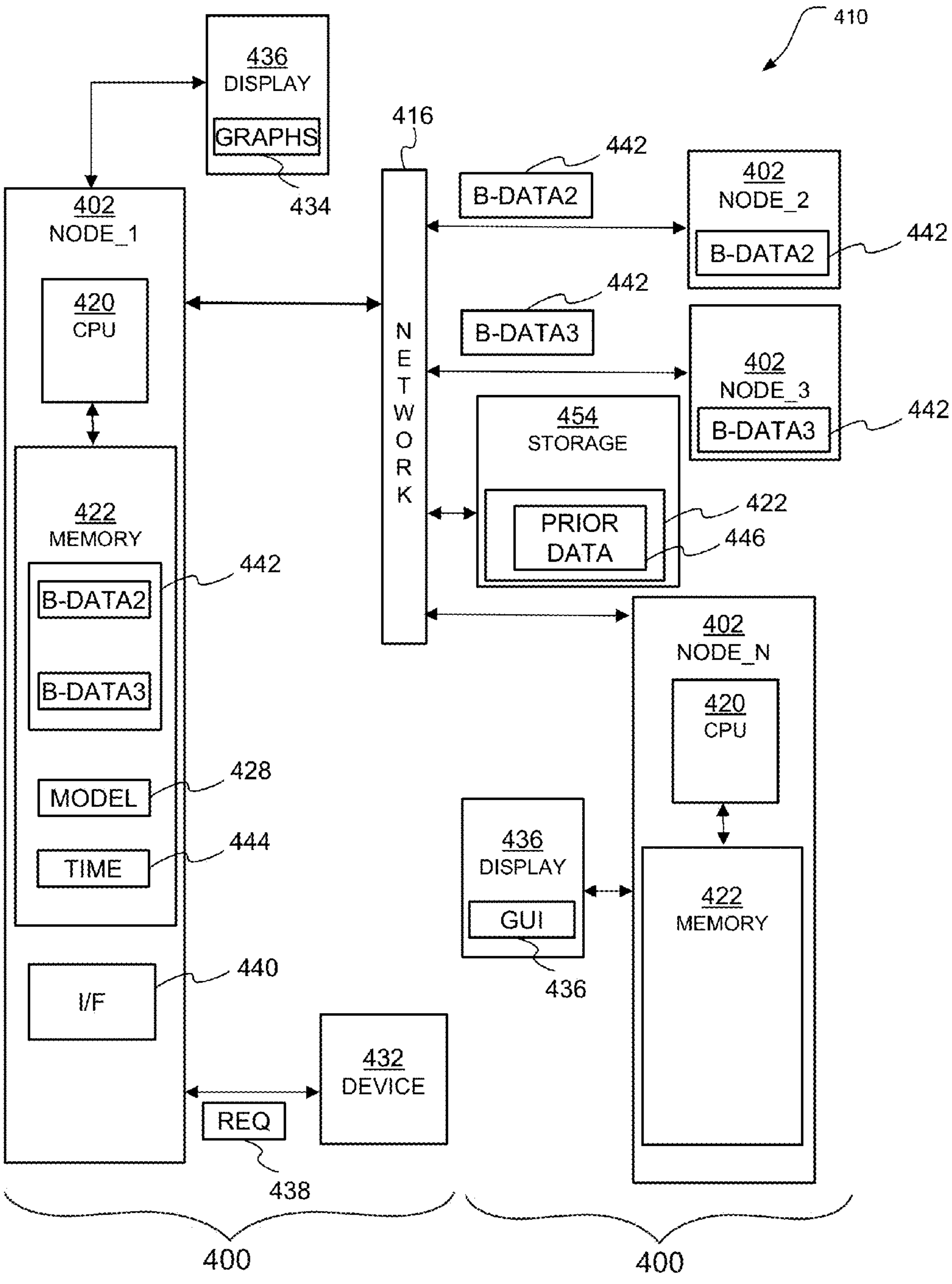

410
436
DISPLAY
GRAPHS
434
416
442
B-DATA2
402
NODE_2
B-DATA2
442
402
NODE_1
420
CPU
442
B-DATA3
402
NODE_3
B-DATA3
442
N
E
T
W
O
R
K
454
STORAGE
PRIOR
DATA
422
446
422
MEMORY
B-DATA2
B-DATA3
442
402
NODE_N
420
CPU
MODEL
428
TIME
444
436
DISPLAY
GUI
436
422
MEMORY
I/F
440
432
DEVICE
REQ
438
400
400

FIG. 4

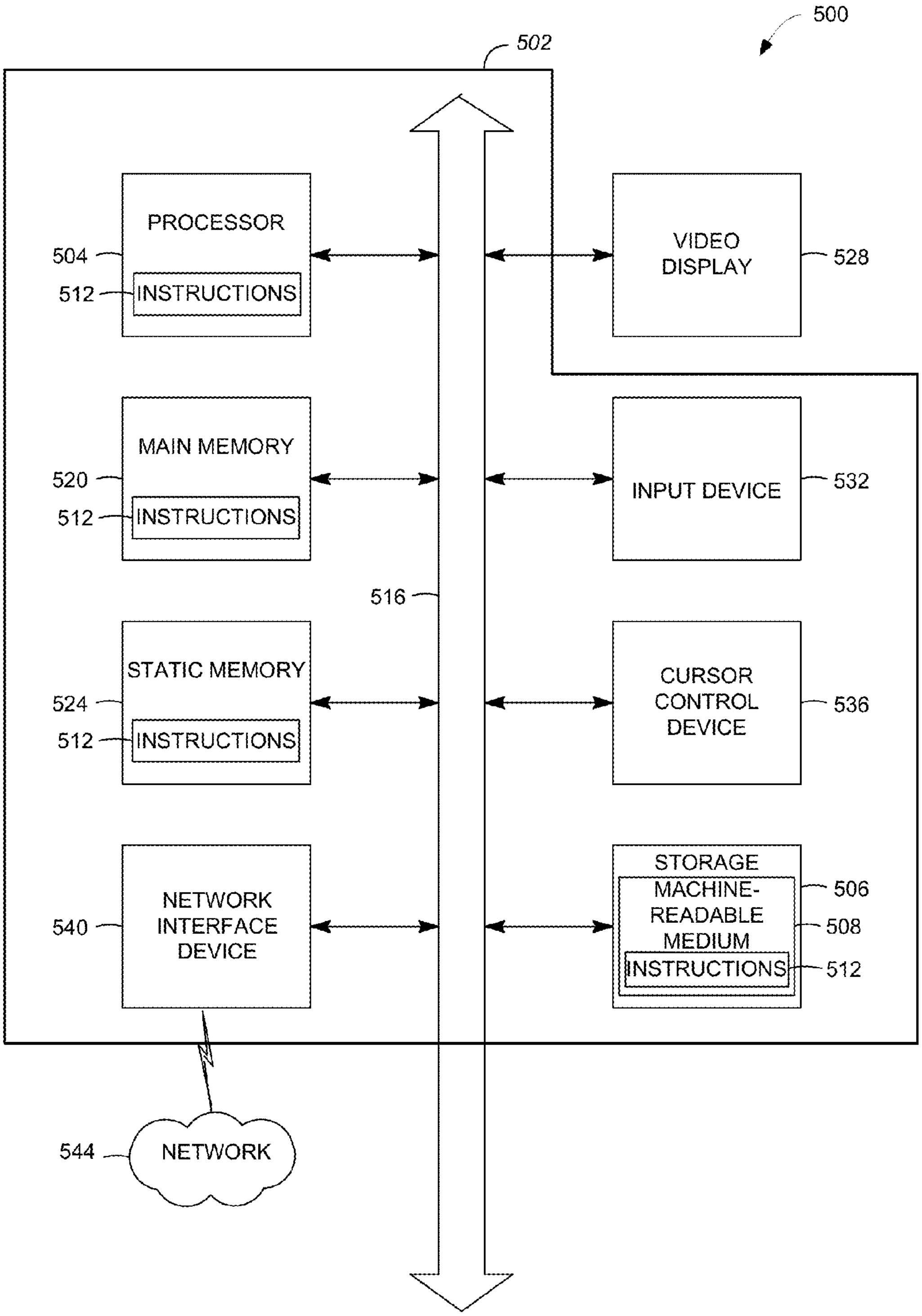

500
502
PROCESSOR
504
512
INSTRUCTIONS
VIDEO DISPLAY
528
MAIN MEMORY
520
512
INSTRUCTIONS
INPUT DEVICE
532
516
STATIC MEMORY
524
512
INSTRUCTIONS
CURSOR CONTROL DEVICE
536
NETWORK INTERFACE DEVICE
540
STORAGE
MACHINE-READABLE MEDIUM
INSTRUCTIONS
506
508
512
544
NETWORK

FIG. 5

EVENT MANAGEMENT APPARATUS, SYSTEMS, AND METHODS

BACKGROUND

[0001] As part of many processes, including the operation of a data processing system, security analysts monitor events that occur. Such monitoring may be used to detect anomalous events, such as a breach of the system security, including those known by persons of ordinary skill in the art as a "security event". Security event management (SEM) systems may be used to provide limited visual cues to alert security analysts to the existence of such anomalies. These cues usually take the form of simple event count charts.

SUMMARY

[0002] In various embodiments, apparatus, systems, and methods that support event management, such as security event management, are provided. In some embodiments, activities include generating a reference statistical model of an operational system (e.g., an operating computer system), and displaying the reference statistical model as a hierarchical, segmented time series event stream graph, along with a graph representing current behavior of the system. The event stream graph may be derived from one or more streams of security events. Additional activities may include receiving requests to display further detail, including hierarchical detail, respecting discrepancies between the reference statistical model and the current behavior. Other embodiments are described, and along with the foregoing examples, will be set forth in detail below.

BRIEF DESCRIPTION OF THE DRAWINGS

[0003] FIG. **1** is a graphical user interface (GUI) illustrating a superposition of event stream graphs for multiple event categories according to various embodiments of the invention.

[0004] FIG. **2** is a GUI illustrating a detailed view of graph superposition for the privilege escalation event category according to various embodiments of the invention.

[0005] FIG. **3** is a flow diagram illustrating methods of operation according to various embodiments of the invention.

[0006] FIG. **4** is a block diagram of apparatus and systems according to various embodiments of the invention.

[0007] FIG. **5** is a block diagram of an article of manufacture, including a specific machine, according to various embodiments of the invention.

DETAILED DESCRIPTION

[0008] A security operations center may use several monitors to display various views that attempt to convey the operational state of one or more processes, such as an operational data processing system. A security analyst monitoring these views creates mental models of what is normal, and what is not. These mental models are not usually driven by specific instances of system behavior, but by patterns derived through experience. To explore apparent deviations from the norm, analysts often rely on additional tools and reports to decide how to spend scarce/expensive resources in order to discover the root of the problem.

[0009] Unfortunately, the visual cues afforded to system administrators by conventional SEM systems do not operate to dynamically classify anomalous events, or to link aggregated event counts to attributes of interest. In addition, no reference models are provided for comparison, to assist the analysts in creating their mental models.

[0010] To address some of the challenges noted above, among others, event management can be implemented to provide a graphic indication of normal and abnormal operations. Anomalous events can be dynamically classified in a hierarchy so that analysts are given visibility not only into statistical deviations from normalcy, but into potential contributing factors.

[0011] In some embodiments, apparatus, systems, and methods are provided for visual, real-time anomaly detection using statistical models. This can be accomplished by comparing reference statistical models with a current statistical model of the system along various security categories and metrics, to visually detect anomalies.

[0012] Statistical streams of events pertaining to specific, arbitrarily deep, hierarchical categories are acquired to statistically model the current state of the system. This model, when compared to various historical, inferred, or predictive reference models, provides cues to the occurrence of anomalies. The presence of a hierarchy in the categorization helps with determining contributing factors at every level of evaluation. The model of the current state also incorporates attributes of interest for every category providing rich details relevant to the statistical streams. Finally, the model incorporates the notion of "state time" which provides the ability to recreate the temporal state of all models at different times, so that the condition of the monitored process over ranges of state time may be selected, and viewed. These views can be reified as time series views, statistical panels, and lists of contextual attribute information that work together to improve the quality of anomaly indications.

[0013] Thus, many embodiments of the invention may be realized, and each can be implemented in a variety of architectural platforms, along with various operating and server systems, devices, and applications. Any particular architectural layout or implementation presented herein is therefore provided for purposes of illustration and comprehension only, and is not intended to limit the various embodiments that can be realized.

[0014] FIG. **1** is a graphical user interface (GUI) **100** illustrating a superposition of event stream graphs **110** for multiple event categories **114** according to various embodiments of the invention. In this case, the graphs **110** are shown with an overview of the corresponding categories **114**, along with a time machine **118** (that can be used to select a range of state time for a more detailed graphic view of events).

[0015] It should be noted that while the specific mechanism described herein reifies the current and reference system models as a time series, various embodiments are not to be so limited. That is, statistical modeling is not limited to time series—other modeling techniques may be used. Thus, the examples illustrated are shown to simplify the explanation of the operation of various embodiments, since it is relatively easy to model normal behavior as a collection of univariate time series, along a variety of corresponding categories.

[0016] There are several components that can work together to provide the functionality described. These include the acquisition of data streams, storage of the streams as time series, implementing a categorical hierarchy, tracking contextual attributes, and a time machine display with selectable compression/expansion. The function of each component will now be described in conjunction with FIG. **1** and FIG. **2**.

[0017] System events, including security events, can be acquired from a variety of sources. Such events include login attempts, virtual machine instantiation, running specific applications, requesting data from specific databases, etc. These event streams can be converted into segmented, categorized statistical streams.

[0018] The categorized statistical streams can be stored as a time series, which provides a way to compare data for different segments of the time series, and/or to compare different statistics derived from the time series. The superposition of these different statistical streams, along with reference streams, rendered as visible graphs **110** forming part of a GUI, enables the rapid visual detection of anomalies as they relate to categories of interest.

[0019] In this case, a reference model graph **122** (e.g., taken from historical data) is shown in superposition with the current behavior graph **126** (e.g., taken from data acquired and displayed in real-time). It should be noted that reference curves displayed for analysis are not limited to historical models. In some embodiments, predictive or calculated reference curves may also be shown.

[0020] Upon viewing the graphs **110**, the appearance of anomalous behavior is readily apparent as a divergence between the graphs at time **130**. At this point, the analyst may decide that the category of privilege escalation **134** bears more detailed investigation, based on the deviation of bad login alerts and the relatively high ranking of the privilege escalation category event counts among all other categories displayed as part of the GUI **100**. Since the categorized data is hierarchical, it is possible to drill down into sub-categories and their related statistical streams. A more detailed view can aid, for example, in determining the factors that contribute to a particular anomaly.

[0021] FIG. **2** is a GUI **200** illustrating a detailed view of graph superposition for the privilege escalation event category **234** according to various embodiments of the invention. Here the reference and current behavior model graphs **210** for privilege escalation events are shown, along with details for a variety of sub-categories **238** associated with privilege escalation events, and their contextual attributes **242**.

[0022] As shown in FIG. **2**, the GUI **200** can be tabbed **246** to provide a dashboard, including a statistical view that enables analysts to perform statistical analysis on a subset of security events using a classification algorithm. When the analyst creates a view, a filter is specified, and a classifier is selected—perhaps from a dropdown menu. The filter ensures that only events matching that filter will be forwarded to the classification algorithm. The classification algorithm processes the events it receives, and creates hierarchical categories over which time series are generated and displayed for analysis.

[0023] In some embodiments, tabs **246** can be used to target a specific area, such as a specific office or grouping of personnel in an organization (e.g., purchasing; receiving; accounting; or role responsibility in a development office, such as a visitor, tester, engineer, or manager). The combination of events that are selected provides a specific statistical segment to be analyzed.

[0024] As a more concrete example, consider a time series for privilege escalation events associated with financial asset system operations (e.g., payment card industry (PCI) data processing system). The acquired event stream can be segmented to look at events associated with defined assets, using event taxonomy. The counts for privilege escalations can be displayed as a real-time (current behavior) graph **226** of the time series. A reference behavior graph **222** for privilege escalations can also be displayed, perhaps as a time series of event counts over the same period of time one week earlier, or averaged over the last four weeks, over the same time period. If the graph **226** of current behavior counts is superimposed on the reference graph **222** and visually demarcated, the analyst can immediately determine where deviations have occurred.

[0025] In this case, privilege escalations are further subcategorized into counts for "success" and counts for "failure", among others. Drilling down into the privilege escalations category provides a detailed view of the sub-categorized counts for the time period of interest. This helps the analyst determine a contributing factor to the perceived anomaly using the sub-categories (e.g., perhaps the anomaly was caused by an increase in "failures", for a variety of reasons). For example, a success count may be related to the number of successful web site login events, while failure represents the number of failed attempts to login to the web site. A sharp rise in login failures may point to the activity of an Internet robot or some other application attempting to infiltrate a secure site.

[0026] The hierarchical nature of the GUI display in FIGS. **1** and **2** can be very useful to the security analyst. This is because deviations between the current and the reference time series (e.g., see times **130**, **230** in the figures) indicate anomalous behavior in real-time, which can be further investigated via categories. The hierarchical category breakdown table displays categories **114** that together make up the display time series graph **126**. Thus, the time series displayed in the dashboard GUI **100** breaks down into the various categories **114** shown in the breakdown table.

[0027] For each category **114** in the breakdown table, the statistical deviation **116** from the reference, such as averaged historical behavior, can be observed (e.g., see the graphs **210** for the category "privilege escalation"). These attributes can be made available at all levels within the hierarchy tree.

[0028] Thus, when an analyst clicks on "success" as a subcategory **238**, the graphs **210** will be displayed for the current behavior and the reference time series with reference to the "success" subcategory, and the category breakdown table will show how the "success" sub-category itself breaks down into various sub-sub-categories (not shown in the figures).

[0029] If the sub-category "success" happens to be the last child in the hierarchy, the category breakdown table would offer no further information in may embodiments. However, the analyst may be informed as to the numeric event count, as well as the maximum counts, the minimum counts, and the median number of counts over the displayed time period, or some selected time period.

[0030] In some embodiments, the system provides contextual attribute information for each categorized event path. These may include attributes **242** that are specific to the category of event for which the graphs **210** are currently displayed. These attributes **242** may comprise items such as the source IP (Internet Protocol) address, the destination IP address, the user account profile, and so on. The values of attributes can be ranked in order of their frequency of occurrence, providing additional assistance to the analyst working to determine the cause of an anomaly.

[0031] For example, as shown in FIG. **2**, categorized information is provided, in addition to the sub-categorized views. In this case, the analyst may be allowed to view the top ten values for the source and destination IP addresses in addition to the top ten values for user accounts addresses derived from the event stream for the period of interest. This ranking of attributes **242** assists the analyst in deciding how to spend valuable time in pursuit of the anomaly. In some embodiments, the analyst is permitted to drill further down into individual ones of the attributes, to view the events involved (not shown).

[0032] The contextual event attributes **242** provide the user with specific information about the deviation from normalcy in terms of (in this case) the source IP address, username, filename accessed, etc. This information allows the analyst to rapidly narrow down a statistical deviation from a high level abstract concept (e.g., as shown in the graphs **110**) to a set of users, a particular machine, a specific file, etc. The set of attributes provided depends on the category the analyst is investigating, and can be used to set the context for forensic analysis of statistical deviation for a specific category.

[0033] The set of attributes **242** can include anything that might be of interest as an indicator of anomalous behavior for a given category. For example, an attribute set could include a list of correlation rules (e.g., the privilege escalation rule **150** that was activated during a selected time period. Since correlation rules can be used to encode policy, the analyst will get a better understanding of specific activities within the system that were operational during the period of interest. In some embodiments, an anomaly engine applies rules as thresholds to certain categories, which are alerted when the rule is violated. A sample rule might be phrased as "inform me when email traffic takes up 90% of all traffic coming out of the network", indicating a spam mailing event, for example.

[0034] A time machine **118** can be provided to permit viewing behavior models in real time mode, or in historical mode. The time machine **118** provides the ability to re-create the state of the system at a given moment in time. All of the corresponding statistical models (e.g., in the form of a graphic time series), along with metrics and contextual attributes at all levels in the hierarchy can be re-created, providing the analyst with a view into the state of the system at some particular time of interest. The ability to go back in time to view system activity is related to the amount of storage available, and the retention policy used in conjunction with the deployed system. Predictive viewing, using predictive extrapolation of the current behavior model, is also possible.

[0035] The ability to view the state of the system for any period (constrained by retention policies) is a powerful addition to the other tools provided. The analyst can traverse the hierarchy backwards and forwards in time, to give a continuous view of anomaly activity and investigation. Thus, the time machine "state of the system" includes the sub-categorized views, and the related information described above.

[0036] For the purposes of this document, a "process" is an interrelated set of computer system activities (e.g., data entry, login, file create, change, store, access, delete) that generate events (the conjunction of an activity, a role for the acting entity, and the object that's acted upon). Events thus arise from the activity of an entity associated with a role, acting on an object.

[0037] Inferences can be drawn from a process, such as what should be happening within secure, vulnerable, and exploited machines; or whether the volume of data on an exploited network equates to normal behavior (e.g., five Gbytes of data received per hour), or abnormal behavior (five Gbytes of data received per minute). Therefore, many additional embodiments may be realized.

[0038] For example, FIG. **3** is a flow diagram illustrating methods **311** of operation according to various embodiments of the invention. The methods **311** are implemented in a machine-accessible and readable medium, and are operational over processes within and among networks. The networks may be wired, wireless, or a combination of wired and wireless. The methods **311** may be implemented as instructions, which when executed by a specific machine, operate to perform the processing depicted in FIG. **3**.

[0039] Some embodiments include generating a reference statistical model of a process, such as an operating computer system (i.e., a domain specific implementation of the method). The method **311** may include displaying the reference statistical model as a hierarchical, segmented time series event stream graph, along with a graph representing current behavior of the process (e.g., an operating computer system). Additional activity may include receiving requests to display further detail surrounding a particular category (or sub-category) in a hierarchy, the detail being associated with discrepancies between the reference statistical model and the current behavior.

[0040] Thus, a method **311** may begin at block **321** with acquiring system operational data in real time, to be stored as historical data. The historical data is used to create a reference statistical model of the system, perhaps by transforming the historical data into segmented, categorized statistical streams. Thus, the method **311** may continue on to block **325** with generating a reference statistical model of a process, such as an operating computer system. The reference statistical model of the process then serves as the basis for comparison with current behavior. For example, as noted previously, the reference statistical model may comprise an average of the data acquired over several weeks, during the same time period for the current week. These time periods, and a variety of others can be selected for display by accessing the time machine range controls (e.g., slider buttons shown in FIGS. **1** and **2**).

[0041] A graph representing current behavior can be created from acquired streams of data. In this case, the streams of data are acquired in real time and immediately used to create the graph. Thus, the method **311** may include receiving a hierarchy of statistical data streams at block **329**. The method **311** may continue on to block **333** with generating a graph representing current behavior from the statistical data streams that have just been acquired, and generating a graph of the reference statistical model, using historical (stored) data. The historical and real-time acquired data can be displayed directly, or processed and/or filtered according to one or more statistical algorithms (e.g., a regular or exponential moving average may be applied to the data).

[0042] In some embodiments, alerts can be published to the user console. Prior to publication, the alerts are generated. Thus, the method **311** may continue on to block **335** to include the generation of alerts (perhaps using an anomaly engine to detect deviations and/or threshold crossings in the acquired data).

[0043] The method **311** may continue on to block **337** with displaying the reference statistical model as a hierarchical, segmented time series event stream graph, along with a graph representing current behavior of the process.

[0044] The graphs may be displayed as a superposition of information, to make visual detection of anomalies easier.

Thus, the activity at block **337** may include displaying the segmented time series event stream graph and the graph representing current behavior as a superposition of graphs in a GUI, such that a divergence between the graphs makes the presence of anomalies readily apparent.

[0045] The hierarchy can be published as a list of ordered categories. Thus, the GUI may comprise a list of event categories in the hierarchy, ordered according to a percentage difference between the current behavior and the reference statistical model for the categories. Other ranking metrics are possible.

[0046] The GUI may include a time machine that offers the opportunity to view process activity (reference and current) over some selected amount of time in the past, or even as predicted for the future. This tool may be offered when both reference and current behavior data are stored, and made available for later recall. The time machine timeline can be adjusted to compress or expand the display over time. Thus, in some embodiments, the GUI may comprise a compressed graphical representation of the current behavior over time, with selectable expansion viewpoints (see FIGS. **1** and **2**).

[0047] In some embodiments, the process comprises multiple processes, such as those making up an operating computer system. In this case, the method **311** includes generating a reference statistical model of the operating computer system. The method **311** may further include displaying the reference statistical model as a hierarchical, segmented time series event stream graph, along with a graph representing current behavior of the operating computer system, wherein the event stream graph is derived from at least one stream of security events.

[0048] The GUI that is published may include a current display of reference/actual event activity, and a time machine display. Thus, the activity at block **337** may comprise presenting an option to view the reference statistical model and the graph representing current behavior in substantially real time, or as historical information recorded from a past time, or both.

[0049] As noted previously, alerts can be published to the user console, perhaps based on deviations within categories (for e.g. alerting when the deviation between current and reference login activity exceeds some threshold) or on interactions between categories (e.g., alerting when the success/failure ratio for a monitored activity is less than some threshold value over a give time period). Thus, the activity at block **337** may comprise publishing statistical alerts based on rules incorporating interactions between multiple categories in the hierarchy.

[0050] The graphs that are published (e.g., displayed on a client terminal display) may take many forms, including volume-based data (e.g., the number of times the same activity is repeated over a given time interval), and frequency-based data (e.g., the number of different activities that occur over a given time interval). Thus, the activity at block **337** may comprise displaying the segmented time series event stream graph to include at least one of a volume-based stream or a frequency-based stream.

[0051] Contextual event attributes can be displayed as a graph that is ordered according to frequency. Thus, the activity at block **337** may also comprise publishing contextual event attributes as a graph of the attributes ordered and numbered according to occurrence frequency (e.g., see FIG. **2**).

[0052] The hierarchy can be explored by drilling down into various categories. Thus, the activity at block **337** may comprise publishing the hierarchy as a list with at least a root level (shown generally in FIG. **1**), an activity level (shown as categories **114**), and an outcome level (e.g., as sub-categories **238**), to enable drill-down level selection.

[0053] When sub-categories are available for inspection and analysis, the system analyst may therefore make a request to view the data associated with these levels. Thus, the method **311** may continue on to block **341** to determine whether such a request has been made. If not, then the method **311** may continue on to block **329**, to acquire more real time data. If so, then the method **311** may continue on to block **345** with receiving requests to display further detail in the hierarchy respecting discrepancies between the reference statistical model and the current behavior.

[0054] The requests to display discrepancies may originate in the selection of lower-level categories in the hierarchy of events. Thus, the activity at block **345** may comprise receiving at least one of the requests in response to selection of a hierarchical category of potential contributing factors.

[0055] The requests to display detail may be serviced by publication to a network client. Thus, the method **311** may go on to block **349** to include transmitting at least some of the further detail to a network interface in a client node coupled to a display.

[0056] The details of current system behavior can be published as part of the GUI. Thus, the method **311** may continue on to block **353** with publishing the further detail as part of an interactive GUI on a display, including an administrator display, a security analyst display, or a client node display.

[0057] The methods described herein do not have to be executed in the order described, or in any particular order. Moreover, various activities described with respect to the methods identified herein can be executed in repetitive, serial, or parallel fashion. The individual activities illustrated using FIGS. **1-3** can also be combined with each other and/or substituted, one for another, in various ways. Information, including parameters, commands, operands, and other data, can be sent and received in the form of one or more carrier waves. Thus, many other embodiments may be realized.

[0058] The activities shown in FIGS. **1-3** can be implemented in various devices, as well as in a computer-readable storage medium, where the methods are adapted to be executed by one or more processors. Further details of such embodiments will now be described.

[0059] FIG. 4 is a block diagram of apparatus **400** and systems **410** according to various embodiments of the invention. Here it can be seen that an apparatus **400** used to provide event management, such as security event management, may comprise one or more processing nodes **402**, one or more processors **420**, multiple memories **422**, and/or displays **436**. The apparatus **400** may comprise a client, a server, or some other networked processing node.

[0060] The processing nodes **402** may comprise physical machines or virtual machines, or a mixture of both. The nodes **402** may also comprise networked entities, such as servers and/or clients. In some basic implementations, the operations described can occur entirely within a single node **402**. The apparatus **400** may thus comprise a single desktop computer or server, for example, or a number of networked nodes **402**.

[0061] In some embodiments, then, an apparatus **400** or system **410** may comprise interface hardware **440** to receive current behavior data **442** representing events occurring within a process, such as an operating computer system. The apparatus **400** may further comprise one or more processors **420** to generate a display of a reference statistical model **428**

of the process, along with a graph representing current behavior of the process (e.g., graphs **434**), wherein the reference statistical model **428** is to be displayed as a hierarchical, segmented time series event stream graph.

[0062] The processor **420** may operate to accept requests **438** to display further detail in a hierarchy respecting discrepancies between the reference statistical model **428** and the current behavior, perhaps as part of a GUI **436**. Thus, the apparatus **400** or system **410** may comprise a GUI **436**. The GUI **436** may be executed by a client node (e.g., NODE_N) to receive and display the hierarchy, along with the graphs **434**.

[0063] Sources of behavior data can be servers, clients, storage nodes, etc. Thus, the behavior data **442** may be received from hardware processing nodes (e.g., nodes NODE_**2** and NODE_**3**) comprising at least one of server nodes, client nodes, or storage nodes (e.g., storage unit **454**).

[0064] The apparatus **400** or system **410** may comprise a time machine module **444** to recall and re-create a state of the process at a past time, to include prior metrics and prior contextual event attributes, perhaps stored as prior data **446** in a memory **422** forming part of a storage unit **454** (e.g., a disk array).

[0065] User account information can be presented in ranked format, correlated to process activity. Thus, the prior contextual event attributes may include user account activity values stored in a memory **422**.

[0066] Address information can be presented in ranked format, and correlated to process activity. Thus, the prior contextual event attributes may include one or more of source address activity values or destination address activity values. These values may be stored in a memory **422** as well.

[0067] In some embodiments, the apparatus **400** may comprise a user input device **432**, perhaps operating as the client node. The request **438** for further detail may originate from the user input device **432**.

[0068] Processing elements and storage devices may be constructed as a single unit, or operated separately. Thus, in some embodiments, the processors **420** may be housed together with the storage unit **454**. The storage unit **454** may comprise volatile memory, non-volatile memory, or a combination of the two.

[0069] A system **410** that operates to manage events may comprise multiple instances of the apparatus **400**. The system **410** might also comprise a cluster of nodes **402**, including physical and virtual nodes. It should be noted that any of the nodes **402** may include any one or more of the elements explicitly shown in nodes NODE_**1**, NODE_**2**, NODE_**3**, . . . , NODE_N, in any combination.

[0070] The nodes **402** may exist as a device embedded within another structure (e.g., as an embedded device), or as a regular desktop or laptop computer that includes a display **436** to show the activities conducted while nodes **402** are active. Thus, the apparatus **400** may also comprise a display **436** coupled to the nodes **402** to display visible indications of the activities conducted (e.g., receiving the request **438**) by the nodes **402**.

[0071] The apparatus **400** and system **410** may be implemented in a machine-accessible and readable medium that is operational over one or more networks **416**. The networks **416** may be wired, wireless, or a combination of wired and wireless. The apparatus **400** and system can be used to implement, among other things, the processing associated with the activities illustrated in FIGS. **1-3**. Modules may comprise hardware, software, and firmware, or any combination of these. Additional embodiments may be realized.

[0072] For example, FIG. **5** is a block diagram of an article **500** of manufacture, including a specific machine **502**, according to various embodiments of the invention. Upon reading and comprehending the content of this disclosure, one of ordinary skill in the art will understand the manner in which a software program can be launched from a computer-readable medium in a computer-based system to execute the functions defined in the software program.

[0073] One of ordinary skill in the art will further understand the various programming languages that may be employed to create one or more software programs designed to implement and perform the methods disclosed herein. The programs may be structured in an object-orientated format using an object-oriented language such as Java or C#. Alternatively, the programs can be structured in a procedure-orientated format using a procedural language, such as assembly or C. The software components may communicate using any of a number of mechanisms well known to those of ordinary skill in the art, such as application program interfaces or interprocess communication techniques, including remote procedure calls. The teachings of various embodiments are not limited to any particular programming language or environment. Thus, other embodiments may be realized.

[0074] For example, an article **500** of manufacture, such as a computer, a memory system, a magnetic or optical disk, some other storage device, and/or any type of electronic device or system may include one or more processors **504** coupled to a machine-readable medium **508** such as a memory (e.g., removable storage media, as well as any tangible, non-transitory memory including an electrical, optical, or electromagnetic conductor) having instructions **512** stored thereon (e.g., computer program instructions), which when executed by the one or more processors **504** result in the machine **502** performing any of the actions described with respect to the methods outlined above.

[0075] The machine **502** may take the form of a specific computer system having a processor **504** coupled to a number of components directly, and/or using a bus **516**. Thus, the machine **502** may be similar to or identical to the apparatus **400** or system **410** shown in FIG. **4**.

[0076] Turning now to FIG. **5**, it can be seen that the components of the machine **502** may include main memory **520**, static or non-volatile memory **524**, and mass storage **506**. Other components coupled to the processor **504** may include an input device **532**, such as a keyboard, or a cursor control device **536**, such as a mouse. An output device **528**, such as a video display, may be located apart from the machine **502** (as shown), or made as an integral part of the machine **502**.

[0077] A network interface device **540** to couple the processor **504** and other components to a network **544** may also be coupled to the bus **516**. The instructions **512** may be transmitted or received over the network **544** via the network interface device **540** utilizing any one of a number of well-known transfer protocols (e.g., HyperText Transfer Protocol). Any of these elements coupled to the bus **516** may be absent, present singly, or present in plural numbers, depending on the specific embodiment to be realized.

[0078] The processor **504**, the memories **520**, **524**, and the storage device **506** may each include instructions **512** which, when executed, cause the machine **502** to perform any one or more of the methods described herein. In some embodiments, the machine **502** operates as a standalone device or may be connected (e.g., networked) to other machines. In a networked environment, the machine **502** may operate in the capacity of a server or a client machine in server-client network environment, or as a peer machine in a peer-to-peer (or distributed) network environment.

[0079] The machine **502** may comprise a personal computer (PC), a tablet PC, a set-top box (STB), a personal digital assistant (PDA), a cellular telephone, a web appliance, a network router, switch or bridge, server, client, or any specific machine capable of executing a set of instructions (sequential or otherwise) that direct actions to be taken by that machine to implement the methods and functions described herein. Further, while only a single machine **502** is illustrated, the term "machine" shall also be taken to include any collection of machines that individually or jointly execute a set (or multiple sets) of instructions to perform any one or more of the methodologies discussed herein.

[0080] While the machine-readable medium **508** is shown as a single medium, the term "machine-readable medium" should be taken to include a single medium or multiple media (e.g., a centralized or distributed database), and/or associated caches and servers, and or a variety of storage media, such as the registers of the processor **504**, memories **520**, **524**, and the storage device **506** that store the one or more sets of instructions **512**. The term "machine-readable medium" shall also be taken to include any medium that is capable of storing, encoding or carrying a set of instructions for execution by the machine and that cause the machine **502** to perform any one or more of the methodologies of the various embodiments, or that is capable of storing, encoding or carrying data structures utilized by or associated with such a set of instructions. The terms "machine-readable medium" or "computer-readable medium" shall accordingly be taken to include tangible media, such as solid-state memories and optical and magnetic media.

[0081] Various embodiments may be implemented as a stand-alone application (e.g., without any network capabilities), a client-server application or a peer-to-peer (or distributed) application. Embodiments may also, for example, be deployed by Software-as-a-Service (SaaS), an Application Service Provider (ASP), or utility computing providers, in addition to being sold or licensed via traditional channels.

[0082] Implementing the apparatus, systems, and methods described herein may operate to provide new options for managing events, such as security events.

[0083] For example, in many embodiments, various classification algorithms can be used to create hierarchical categories that can drive visual analysis along various dimensions. At the time of creating a particular statistical view, analysts can select an algorithm to associate with that view. That algorithm then drives the categorization of data visible to that view. N classifiers can be created, as well as N reference curves. Reference curves can be dynamically generated over time.

[0084] Most embodiments can function using any type of data stream, with classifiers added to operate on those streams. The generated stream of counts can thus be converted into different statistical streams and stored.

[0085] For example, in some embodiments, a taxonomy classifier having three levels of hierarchy is used. The first level is a root level, comprising mostly a time series of all the data visible in that view (as specified by the corresponding filter). The second level is the activity or taxonomy name level. This level generally corresponds to the type of activities being performed within the events being processed. Categories in this level include "logins" and "file deletes". The third level is the outcome level. Outcomes for each category in the second level include items such as "success", "failure", "unknown", etc. FIG. **2** shows additional examples for these sub-categories **238**.

[0086] In some cases, a system to manage events, such as security events, may be designed as a pluggable system, to enhance the potential for reuse across environments.

[0087] Using the combination of the features made available by various embodiments may lead to more efficient monitoring of various process types, including an operating computer system. Increased efficiency in system administration, rapid fault detection, and better operational security may result.

[0088] This Detailed Description is illustrative, and not restrictive. Many other embodiments will be apparent to those of ordinary skill in the art upon reviewing this disclosure. The scope of embodiments should therefore be determined with reference to the appended claims, along with the full scope of equivalents to which such claims are entitled.

[0089] The Abstract of the Disclosure is provided to comply with 37 C.F.R. §1.72(b) and will allow the reader to quickly ascertain the nature of the technical disclosure. It is submitted with the understanding that it will not be used to interpret or limit the scope or meaning of the claims.

[0090] In this Detailed Description of various embodiments, a number of features are grouped together in a single embodiment for the purpose of streamlining the disclosure. This method of disclosure is not to be interpreted as an implication that the claimed embodiments have more features than are expressly recited in each claim. Rather, as the following claims reflect, inventive subject matter lies in less than all features of a single disclosed embodiment. Thus the following claims are hereby incorporated into the Detailed Description, with each claim standing on its own as a separate embodiment.

What is claimed is:

1. A system, comprising:

interface hardware to receive current behavior data representing events occurring within a process; and

at least one processor to generate a display of a reference statistical model of the process, along with a graph representing current behavior of the process, wherein the reference statistical model is to be displayed as a hierarchical, segmented time series event stream graph, and wherein the processor is to accept requests to display further detail in a hierarchy respecting discrepancies between the reference statistical model and the current behavior.

2. The system of claim **1**, further comprising:

a graphical user interface (GUI) executed by a client node to receive and display the hierarchy, along with the graphs.

3. The system of claim **1**, wherein the behavior data is received from hardware processing nodes comprising at least one of server nodes, client nodes, or storage nodes.

4. The system of claim **1**, further comprising:

a time machine module to recall and re-create a state of the process at a past time, to include prior metrics and prior contextual event attributes.

5. The system of claim **4**, wherein the prior contextual event attributes include user account activity values stored in a memory.

6. The system of claim **4**, wherein the prior contextual event attributes include at least one of source address activity values or destination address activity values, the values stored in a memory.

7. A processor-implemented method to execute on one or more processors that perform the method, comprising:

generating a reference statistical model of a process;

displaying the reference statistical model as a hierarchical, segmented time series event stream graph, along with a graph representing current behavior of the process; and

receiving requests to display further detail in a hierarchy respecting discrepancies between the reference statistical model and the current behavior.

8. The method of claim **7**, further comprising:

receiving a hierarchy of statistical data streams; and

generating the graph representing the current behavior from the statistical data streams.

9. The method of claim **7**, further comprising:

displaying the segmented time series event stream graph and the graph representing current behavior as a superposition of graphs in a graphical user interface (GUI).

10. The method of claim **7**, wherein the receiving further comprises:

receiving at least one of the requests in response to selection of a hierarchical category of potential contributing factors.

11. The method of claim **7**, further comprising:

publishing the further detail as part of an interactive graphical user interface (GUI) on a display.

12. The method of claim **9**, wherein the GUI further comprises:

a list of event categories in the hierarchy, ordered according to a percentage difference between the current behavior and the reference statistical model for the categories.

13. The method of claim **9**, wherein the GUI further comprises:

a compressed graphical representation of the current behavior over time, with selectable expansion viewpoints.

14. A processor-implemented method to execute on one or more processors that perform the method, comprising:

generating a reference statistical model of an operating computer system;

displaying the reference statistical model as a hierarchical, segmented time series event stream graph, along with a graph representing current behavior of the operating computer system, wherein the event stream graph is derived from at least one stream of security events; and

receiving requests to display further detail respecting discrepancies between the reference statistical model and the current behavior.

15. The method of claim **14**, further comprising:

transmitting at least some of the further detail to a network interface in a client node coupled to a display.

16. The method of claim **14**, further comprising:

presenting an option to view the reference statistical model and the graph representing current behavior in substantially real time, or as historical information recorded from a past time, or both.

17. The method of claim **14**, further comprising:

publishing statistical alerts based on rules incorporating interactions between multiple categories in the hierarchy.

18. The method of claim **14**, wherein the displaying comprises:

displaying the segmented time series event stream graph to include at least one of a volume-based stream or a frequency-based stream.

19. The method of claim **14**, further comprising:

publishing contextual event attributes as a graph of the attributes ordered and numbered according to occurrence frequency.

20. The method of claim **14**, further comprising:

publishing the hierarchy as a list with at least a root level, an activity level, and an outcome level, to enable drill-down level selection.

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